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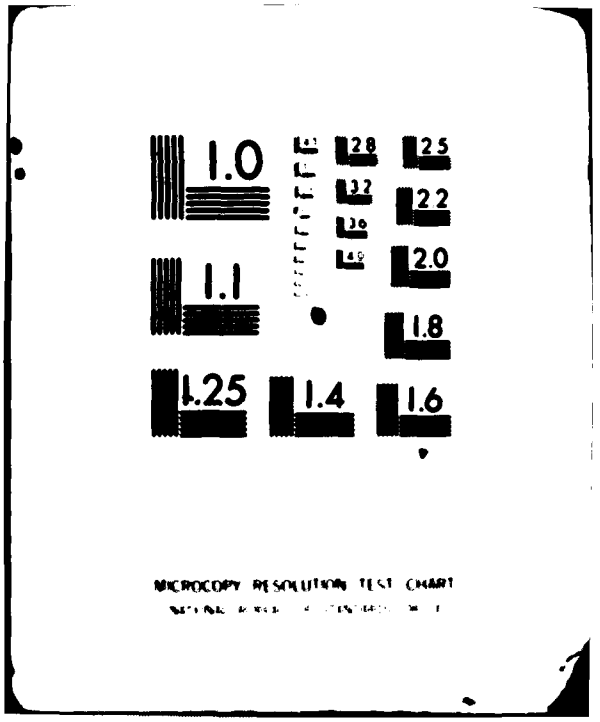
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# Ultrasonic Research Summary Report and Literature Guide to the National Bureau of Standards/Office of Naval Research Program

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Manufacturing Engineering
Washington, DC 20234





June 1982

Government Order N00014-82-F-0004

NBS Principal Investigator: F.R. Breckenridge
ONR Scientific Officer: L.E. Hargrove





Report to
Office of Naval Research
Physics Division Code 412
800 North Quincy Street
Arlington, VA 22217

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# ULTRASONIC RESEARCH SUMMARY REPORT AND LITERATURE GUIDE TO THE NATIONAL BUREAU OF STANDARDS/OFFICE OF NAVAL RESEARCH PROGRAM

M Greenspan and D G Eitzen

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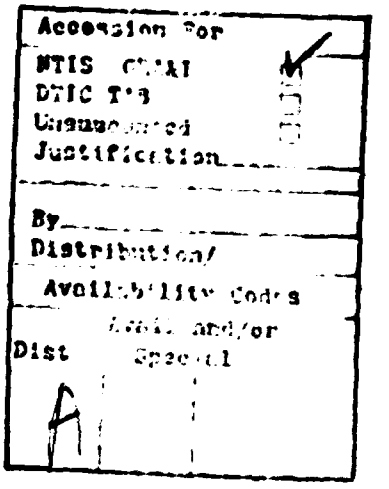
U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

## ABSTRACT

This brief report summarizes research efforts in physical acoustics at the National Bureau of Standards (NBS) which were partially supported by the Office of Naval Research (ONR). It summarizes what we think are many of the major accomplishments at NBS in the area of physical acoustics from 1948 to 1981. The published literature documenting these successes is listed.





## Introduction

The physical acoustic work referred to here was performed at the National Bureau of Standards and was partially supported by the Office of Naval Research (ONR). The work was begun in 1948 under contract NA-ONR-70-48 when the ONR (b. 1946) was in its swaddling clothes and continues today with support that we gratefully acknowledge. The relationship has been not only a productive one but also an amiable one. Perturbations in the technical direction of the work were not paralleled by perturbations in the relationship, except for such occasions as he first time we started including an overhead charge (then a whopping 15%) on top of direct costs.

## Accomplishments

The major accomplishments of the ONR supported physical acoustics project and its extensions are listed below. Of course, many other avenues were explored, but since our hope is that this listing will guide the reader to the published outputs of this project, we have refrained from listing the several interesting but unproductive deadends. The superscripts refer to the bibliography and the initials denote the people involved as follows: CET, Carl E. Tschiegg; FRB, Franklin R. Breckenridge; JHW, John H. Wasilik; MCT, Moody C. Thompson, Jr.; MG, Martin Greenspan; NNH, Nelson N. Hsu; RKC, Richard K. Cook; TMP, Thomas M. Proctor, Jr.

(1) Performed first measurements of translational dispersion in monatomic gases. Still serves as the standard against which new methods in theory of non-uniform gases are tested. (MG, MCT)[1,2,3,4,15,23,25]

(2) Made accurate measurements of rotational collision numbers in nitrogen, oxygen, and air. (MG)[20]

(3) Developed an algorithm for combining the effects of translational and thermal-relaxational dispersion of sound. (MG)[6,9]

(4) Developed the first theory for and later made the first measurements of free-molecule propagation of sound. (RKC, MG, MCT)[7]

(5) Developed first practical underwater velocimeter, which is now in wide use not only in sonar and oceanography but also in industrial process control.[11,17,18,21] Also developed associated calibration methods.[12,13,16,19] This work resulted in a Department of Commerce Meritorious Award (Silver Medal) as well as an IR-100 Award (for the manufacturer). (MG, CET)

(6) Made high-precision determination of the effect of dissolved air on the speed of sound in water. (MG, CET)[12]

(7) Performed pioneer studies of anelasticity in a-quartz at elevated temperatures. (RKC, JHW).[14,14a]

(8) Determined elastic constants of ice-I at temperatures from room down to pumped $N_2$. (TMP)[28]

(9) Showed that if properly designed and carefully executed techniques for measuring compliance are employed, the so-called "audio-frequency resonances" of Fitzgerald do not appear. (MG, CET)[22,24]

(10) Developed simple methods of making reproducible cavitation measurements in suitably prepared liquids, so that the effects of the nuclei can be separated from those owing to the intrinsic properties of the liquid. (MG, CET)[27,29,33]

(11) Developed a method for the calibration of miniature hydrophones (probes), using independently measured radiation-induced cavitation thresholds as standards. (MG, CET)[27]

(12) Showed that there are certain inherent limitations on the realizable acoustical properties of fluids and viscoelastic materials. In particular, no "ideal absorber," a desideratum in underwater sound applications, can be constructed from a homogeneous, single-component material. (MG)[30]

(13) Elucidated the theory of the resonator-decay method of measuring sound absorption in liquids, and showed that the principal excess loss at the lower frequencies is dissipation in the envelope. (MG)[31]

(14) Verified experimentally, with unprecedented accuracy, the transient solution of Pekeris to Lamb's problem (seismic surface pulse) and adapted the results to the calibration of acoustic-emission transducers. (FRB, CET, MG, TMP)[34]

(15) Designed, built and put into service an absolute capacitive displacement meter for work on surface waves up to 1 MHz. Used in (14) above. (FRB, MG)[40]

(16) Established a calibration service, for the government and the public, for acoustic-emission transducers based on (14) and (15) above.[39,41]

(17) Developed a device, based on modulated radiation pressure, for measurement of total radiated ultrasonic power from a transducer. It is the most accurate, sensitive, and precise method now available and is the basis for a calibration service. The method is most directly applicable to medical and nondestructive evaluation transducers, but it is also useful for monitoring the stability of any transducer (subject to some constraints on size and shape) over the range 1 to 15 MHz, and with some reduction in sensitivity, to 50 MHz or more. (MG, FRB, CET)[35,37]

(18) Generalized the theory of the piston radiator to several new cases. (MG)[36]

(19) Devised a piezoelectric displacement meter of very high output for use as a transfer device and for field applications. Has nearly as high fidelity as the standard capacitive detector [(15) above]. Basis for IR-100 Award (TMP)[42]

(20) Produced an analysis of the transducer of item (19) which may be useful for optimization of design. (NBS report being written.) (MG)

(21) Verified experimentally, for the first time, the transient solution to an infinite plate subject to a step-function force input as calculated by Pao of Cornell U. (Manuscript complete), (TMP, FRB)[43]

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